

A phantom with known geometry should be used, either including markers with known relative coordinates or test objects with known shapes and volumes. The design of the phantom will depend of the modality to be tested.

For ultrasound imaging the AAPM Task Group 128 includes a list with 8 elements of a phantom that allow for all the recommended tests [1]. It is referred to a commercial phantom that include nylon monofilaments in a N-shaped pattern and spherical and non-spherical volume in order to test key imaging parameters such as depth of penetration, axial and lateral resolution, distance, area and volume measurements and geometric consistency.

Roué et al used a commercial PMMA phantom with 25 stainless steel markers with known relative position to check the geometric accuracy of CT and conventional x-ray imaging [2]. A phantom including several inserts with different density can be used to check the volume reconstruction accuracy for CT. Several commercial phantoms are available.

It is well known that geometrical distortions can frequently occur in MR images. The magnitude of the distortions should be investigated by using phantoms with markers or tubes filled with for example Cu²⁺-doped water solution. Additional, the influence of an applicator should also be investigated since for example the presence of a titanium applicator may produce geometric distortion in a high field MR machine.

The slice thickness will also influence the ability to reconstruct the geometry correctly. With too large distance between the slices the partial volume effect will influence the accuracy of the volume reconstruction [3]. On the other hand, de Brabandere et al showed that too small distance between the slices decreased the accuracy of seed detection in a dedicated phantom with agarose gel and 60 iodine seeds with known position using MR imaging [4].

References

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Dose verification

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Any radiotherapy delivery is associated with uncertainties and with risk of misadministration/error. Misadministration/error refers to treatment incidents/accidents which can be prevented, while uncertainties can only be controlled to a certain degree and the residual variation must be accounted for through tolerances and treatment margins. Patient safety through prevention of radiation dose misadministration is highly prioritised and several authorities and societies worldwide are focusing on radiation safety and medical events. In 2004, the International Commission of Radiation Protection (ICRP) reported an analysis of 500 radiation events in BT. This investigation and others have shown that a significant share of radiation events are caused by human errors related to the manual procedures of BT. Verification in radiation therapy means the whole process of proof that planned dose is delivered to the patient within a specific level of accuracy. During the last two decades enormous developments and technological innovations in the field of external beam radiotherapy (EBRT) treatment verification have taken place. These developments have focussed on imaging technologies for 2D and 3D (and very actually also 4D) localization and anatomy reconstruction under treatment delivery conditions. Striking innovations have been imaging technologies such as

flat panel detectors, cone beam CT (CBCT), and most recently MRI, which is integrated with the linear accelerators. The combination of 3D-imaging techniques and dose measurements enables the estimation of the daily 3D-dose delivery in the patient anatomy. In contrast, on-board or real-time treatment verification of BT is currently not performed, simply because adequate tools are not available. There is currently a striking unbalance between the availability of treatment verification technology for EBRT and BT, and consequently a different level of safety. Adding even further to this unbalance, BT is related with higher risk of major dose misadministration than EBRT, since BT involves: 1) more manual procedures (e.g. assembly and implantation of applicators, catheter reconstruction, and guide tube connection), 2) mechanical equipment with a higher susceptibility to malfunction (e.g. source cable drive and applicators), 3) more frequent application of hypofractionation schedules, and finally 4) steeper dose gradients. New methodologies for treatment verification are highly warranted. Dose and source geometry are closely linked entities in brachytherapy. Dose calculation with TG43 is the current standard of dose calculation in brachytherapy, and has excellent accuracy in most clinical scenarios. TG43 is based on geometry. Given a direct correspondence between brachytherapy source geometry and dose, a geometric verification is nearly equivalent to a dosimetric verification. There are only few error scenarios where source geometry would be correct, but not dosimetry - e.g. source miscalibration. Therefore several novel "on-board" treatment verification tools are focused on verification of geometry: EM tracking of catheters, flat panel monitoring of source progression, fluoroscopy, and real-time in vivo dosimetry. Given the source geometry is correct, the next important step is to secure that the relation between sources and anatomy is correct. This last step is typically explored with imaging. Combinations between different verification tools may be the way to proceed to reach a higher level of treatment verification in brachytherapy which address geometry, patient anatomy and consequent dose delivery to the patient. The presentation will outline current developments in "on-board" treatment verification tools. The table below shows the current status of treatment verification in EBRT and BT, and indicates visions that can bring brachytherapy treatment verification forward.

Symposium: Robust and accurate functional MRI for radiotherapy

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Needs and technical requirements for functional MRI in radiotherapy

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Anatomical imaging with T1 and T2-weighted MRI is increasingly used in combination with CT for precise delineation of tumors and normal structures. MRI also offers functional techniques, such as diffusion-weighted MRI (DWI) and dynamic contrast-enhanced MRI (DCE-MRI). These can be applied in radiotherapy for tissue classification, monitoring of treatment response as well as for dose painting. In the diagnostic setting, these sequences are often part of routine scanning protocols. However, as for anatomical MRI sequences, there are some specific issues that need to be considered when applying these techniques in radiotherapy. For image registration with the planning CT, patients need to be scanned in treatment position. If the functional images are used for target delineation, their geometrical fidelity needs to be verified. In particular diffusion-weighted MRI is prone to geometrical distortions. Methods to reduce these distortions will be discussed. The spatial resolution of functional imaging tends to be lower than that of anatomical imaging. Although acquisition with small imaging voxels is feasible, this doesn't mean that the functional quantity (apparent diffusion coefficient for DWI and tracer kinetics parameters for DCE-MRI) can be reliably determined in a